# A PLANNED JEFFERSON LAB EXPERIMENT ON SPIN-FLAVOR DECOMPOSITION

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Experiment E04-113 at Jefferson Lab Hall C plans to measure the beam-target double-spin asymmetries in semi-inclusive deep-inelastic $\vec{p}(e,e'h)X$ and $\vec{d}(e,e'h)X$ reactions ($h=\pi^+,\pi^-,K^+$ or$K^-$) with a 6 GeV polarized electron beam and longitudinally polarized $NH_3$ and LiD targets. The high statistic data will allow a spin-flavor decomposition in the region of $x=0.12\sim 0.41$ at $Q^2=1.21\sim 3.14$ GeV$^2$. Especially, leading order and next-to-leading order spin-flavor decomposition of $\Delta u_v$, $\Delta d_v$ and $\Delta\bar{u}-\Delta\bar{d}$ will be extracted based on the measurement of the combined asymmetries $A_{1N}^{\pi^+-\pi^-}$. The possible flavor asymmetry of the polarized sea will be addressed in this experiment.

## 1. Introduction

Remarkable progress in the knowledge of the polarized quark distributions $\Delta q_f(x)$ has been made in the last decade through inclusive deep-inelastic lepton scattering (DIS). However, the information available from inclusive DIS process has inherent limitations. As the cross sections are only sensitive to $e_q^2$, an inclusive DIS experiment probes quarks and anti-quarks on an equal footing, therefore is not sensitive to the symmetry breaking in the sea sector. The sensitivity to each individual quark flavor can be realized in semi-inclusive deep inelastic scattering (SIDIS) in which one of the leading hadrons is also detected. Recently, the HERMES collaboration published the results of a leading order spin-flavor decomposition from polarized proton and deuteron data, and for the first time extracted the $\bar{u},\bar{d}$ and $s=\bar{s}$

sea quark polarization [1].

The validity of the HERMES method of spin-flavor decomposition relies explicitly on several non-trivial assumptions. First, the leading-order "naive $x$-$z$ factorization" was assumed and the next-to-leading order terms were neglected. This implies that the cross sections factorize into the $x$-dependent quark distributions and the $z$-dependent fragmentation functions:

$$\sigma^h(x,z) = \sum_i e_f^2 q_f(x) \cdot D_{q_f}^h(z), \;\; \Delta\sigma^h(x,z) = \sum_i e_f^2 \Delta q_f(x) \cdot D_{q_f}^h(z). \quad (1)$$

Furthermore, it was assumed that the quark fragmentation process and the experimental phase spaces were well-understood such that a LUND model based Monte Carlo simulation program can reliably reproduce the "purity matrices" which account for the probability correlations between the detected hadrons and the struck quarks [1].

It was pointed out by Christova and Leader [2] that if the combined asymmetries $A_{1N}^{\pi^+-\pi^-}$ are measured, quark polarization $\Delta u_v$, $\Delta d_v$ and $\Delta\bar{u}-\Delta\bar{d}$ can be extracted at leading order without the complication of fragmentation functions. Even at next-to-leading order, information on the valence quark polarizations is well preserved in the combined asymmetries $A_{1N}^{\pi^+-\pi^-}$.

## 2. The Christova-Leader method at LO and NLO

At the leading order, under isospin symmetry and charge conjugation, the fragmentation functions cancel exactly in the combined asymmetry $A_{1N}^{\pi^+-\pi^-}$, the $s$-quark does not contribute, and we have [2] :

$$\begin{aligned} A_{1p}^{\pi^+-\pi^-} &= \frac{\Delta\sigma_p^{\pi^+} - \Delta\sigma_p^{\pi^-}}{\sigma_p^{\pi^+} - \sigma_p^{\pi^-}} = \frac{4\Delta u_v - \Delta d_v}{4u_v - d_v}, \\ A_{1d}^{\pi^+-\pi^-} &= \frac{\Delta\sigma_d^{\pi^+} - \Delta\sigma_d^{\pi^-}}{\sigma_d^{\pi^+} - \sigma_d^{\pi^-}} = \frac{\Delta u_v + \Delta d_v}{u_v + d_v}. \end{aligned} \quad (2)$$

Therefore, measurements of $A_{1N}^{\pi^+-\pi^-}$ on the proton and the deuteron can determine $\Delta u_v$ and $\Delta d_v$. On the other hand, the existing inclusive DIS data already constrains another non-singlet quantity:

$$g_1^p(x,Q^2) - g_1^n(x,Q^2) = \frac{1}{6}\left[(\Delta u + \Delta\bar{u}) - (\Delta d + \Delta\bar{d})\right]|_{LO}. \quad (3)$$

The polarized sea asymmetry can be extracted at leading order following:

$$(\Delta\bar{u} - \Delta\bar{d})|_{LO} = 3(g_1^p - g_1^n)|_{LO} - \frac{1}{2}(\Delta u_v - \Delta d_v)|_{LO}. \quad (4)$$

At the next-to-leading order, $x$ and $z$ are mixed through double convolutions, and instead of Eq. 1, we have:

$$\sigma^h(x,z) = \sum_f e_f^2 q_f \left[1 + \otimes \frac{\alpha_s}{2\pi} C_{qq} \otimes\right] D_{q_f}^h + \left(\sum_f e_f^2 q_f\right) \otimes \frac{\alpha_s}{2\pi} C_{qg} \otimes D_G^h + G \otimes \frac{\alpha_s}{2\pi} C_{gq} \otimes \left(\sum_f e_f^2 D_{q_f}^h\right) \quad (5)$$

and similarly for $\Delta\sigma^h$, where $C$s are well-known Wilson coefficients. The convolution terms become much simpler [2] in quantities relate to $\sigma^{\pi^+} - \sigma^{\pi^-}$ since the $gq$ and $qg$ terms in Eq. 5 are identical for $\pi^+$ and $\pi^-$:

$$A_{1p}^{\pi^+-\pi^-} = \frac{(4\Delta u_v - \Delta d_v)\left[1 + \otimes(\alpha_s/2\pi)\Delta C_{qq}\otimes\right](D^+ - D^-)}{(4u_v - d_v)\left[1 + \otimes(\alpha_s/2\pi)C_{qq}\otimes\right](D^+ - D^-)},$$
$$A_{1d}^{\pi^+-\pi^-} = \frac{(\Delta u_v + \Delta d_v)\left[1 + \otimes(\alpha_s/2\pi)\Delta C_{qq}\otimes\right](D^+ - D^-)}{(u_v + d_v)\left[1 + \otimes(\alpha_s/2\pi)C_{qq}\otimes\right](D^+ - D^-)}. \quad (6)$$

in which $\Delta u_v$ and $\Delta d_v$ evolve as non-singlets and do not mix with gluon and sea distributions. Once we extract $\Delta u_v$ and $\Delta d_v$ at next-to-leading order from Eq. 6, $\Delta\bar{u} - \Delta\bar{d}$ can be determind to next-to-leading order using the well-known NLO form of Eq. 3.

## 3. The Jefferson Lab experiment E04-113

Experiment E04-113 at Jefferson Lab Hall C [3] is specifically designed to have well controlled phase spaces and hadron detection efficiencies such that the combined asymmetries $A_{1N}^{\pi^+\pm\pi^-}$, in addition to the individual asymmetries $A_{1N}^h$ ($h = \pi^+, \pi^-, K^+, K^-$), can be determined with high precision. The existing HMS spectrometer will be used as the hadron detector at 10.8° and a central momentum of 2.71 GeV/c, corresponding to $\langle z\rangle \approx 0.5$ to favor the current fragmentation. For the electron detector, a combination of a large calorimeter array and a gas Cherenkov will be used. The experiment will cover $0.12 < x < 0.41$ with $1.21 < Q^2 < 3.14$ (GeV/c)$^2$ and $2.31 < W < 3.09$ GeV.

In addition to the Christova-Leader method, the "fixed-$z$ purity" method of spin-flavor decomposition will be applied to provide a consistency check. At the well-defined $z$-value of this experiment, the "purity matrices" can be directly calculated based on unpolarized PDFs and the ratio of fragmentation functions, rather than from a Monte Carlo simulation which involves a fragmentation model. The expected statistical accuracies and the estimated systematic uncertainties are shown in Fig.1.

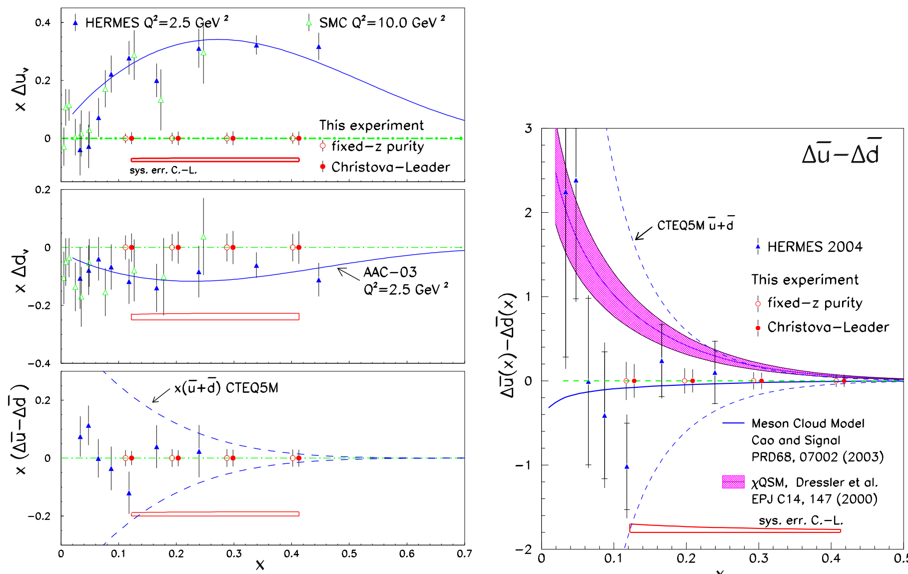


Figure 1. The expected statistical accuracies of experiment E04-113 for two independent methods of flavor decomposition (Christova-Leader and "fixed-$z$ purity") are compared with the HERMES data [1] and the SMC data [4]. The open boxes represent the systematic uncertainties of the Christova-Leader method.

## 4. Conclusions

Experiment E04-113 at Jefferson Lab plans to extract quark polarizations based on the measurement of the combined asymmetries $A_{1N}^{\pi^+-\pi^-}$. The much improved statistics over the HERMES data will present us with the first opportunity to probe the possible flavor asymmetry of the light sea quark polarization.

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